Understanding Future-Viewing Machines and Time Travel*

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1 Introduction

The concept of time travel has been analyzed in philosophical literature for more than sixty years,[1] for obvious reasons, while time viewing seems to have eluded direct attention.[2] However, time viewing offers a similarly challenging range of

*The text of this reformatted version is identical to the original April 6th, 2014 text, except 'outcome-informative' has replaced a former term with the same function and a clarifying comment which starts, "i.e., definite information from...," has been added to the third section.

[1]The most notable early philosophical works include the following: Williams, D. C., "The Myth of Passage," *The Journal of Philosophy*, 48 (1951): 457-472. Putnam, H., "It Ain't Necessarily So," *The Journal of Philosophy*, Vol. 59, No. 22, *American Philosophical Association Eastern Division: Symposium Papers to be Presented at the Fifty-Ninth Annual Meeting*, New York City, December 27-29, 1962 (1962), 658-671. Smart, J. J. C., "Is Time Travel Possible?" *The Journal of Philosophy*, 60 (1963): 237-241. Swinburne, R. G., "Affecting the Past," *The Philosophical Quarterly*, 16 (1966): 341-347. Earman, J., "Going Backward in Time," *Philosophy of Science*, 34 (1967): 211-222. Berger, G., "The Conceptual Possibility of Time Travel," *The British Journal of the Philosophy of Science*, 19 (1968): 152-155. Harrison, J., "The Inaugural Address: Dr. Who and the Philosophers or Time-Travel for Beginners," *Proceedings of the Aristotelian Society, Supplementary Volumes*, Vol. 45 (1971): 1-24. Weingard, R., "On Travelling Backward in Time," *Synthese*, Vol. 24, No 1/2, Space, Time, and Geometry (1972): 117-132. Meiland, J. W., "A Two-Dimensional Passage Model of Time for Time Travel," *Philosophical Studies: An International Journal for Philosophy in the Analytic Tradition*, 26 (1974): 153-173. Horwich, P., "On Some Alleged Paradoxes of Time Travel," *The Journal of Philosophy*, Vol. 72, No. 14, Time, Cause, and Evidence (1975): 432-444. Dwyer, L., "Time Travel and Changing the Past," *Philosophical Studies: An International Journal for Philosophy in the Analytic Tradition*, 27 (1975): 341-350. Thom, P., "Time-Travel and Non-Fatal Suicide," *Philosophical Studies: An International Journal for Philosophy in the Analytic Tradition*, 27 (1975): 211-216. Lewis, D., "The Paradoxes of Time Travel," *American Philosophical Quarterly*, 13 (1976): 145-152. Dwyer, L. "How to affect, but not change, the past," *The Southern Journal of Philosophy*, 15 (1977): 383-385. Weingard, R., "General Relativity and the Conceivability of Time Travel," *Philosophy of Science*, 46 (1979): 328-332.

[2]Time viewers will here be defined as systems which are able to receive images of past or future scenes and convey them to our eyes, or in the case of eyes, to our optic nerves. Conceptually, at least, time viewers come in three main varieties which will be introduced in the text: line-of-sight past viewers, chronovisors, and future viewers. Philosophical writings devoted to chronovisors and future viewers, prior to the present work, seem to be absent from the literature. However, related concepts raised in analyses of human precognitive abilities and the possibility of backward causation have been extensively discussed. The following references provide an overview of these topics: Dunne, J. W., *An Experiment with Time*,

potential contradictions which call for resolution, in the context of future viewing. The central question of time travel concerns whether use of a time machine could cause paradoxical changes to the past, or not. A rich atmosphere of interdisciplinary efforts has recently culminated in a definite answer: Physicists and engineers have developed a model of pastward time travel which elegantly explains why anyone who succeeds to travel to the past in the manner permitted within general relativity could not change it in any way.[3] The most relevant aspects of this groundbreaking result, and the quantum teleportation experiments which support it, are detailed here. On the other hand, the central problem of time viewing is to understand how logical possibility would define the effects and

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2nd edition (London: A. & C. Black, Ltd., 1929). Broad, C. D., "Mr. Dunne's Theory of Time in 'An Experiment with Time,'" Philosophy, 10 (1935): 168-185. Broad, C. D., "The Philosophical Implications of Foreknowledge," *Proceedings of the Aristotelian Society, Supplementary Volumes*, Vol. XVI, 'Knowledge and Foreknowledge' (1937): 177-209. Price, H. H., "The Philosophical Implications of Precognition," *Proceedings of the Aristotelian Society, Supplementary Volumes*, Vol. XVI, 'Knowledge and Foreknowledge' (1937): 211-228. Price, H. H., "Some Philosophical Questions about Telepathy and Clairvoyance," *Philosophy*, 15 (1940): 363-385. Broad, C. D., "The Experimental Establishment of Telepathic Precognition," *Philosophy*, 19 (1944): 261-265. Mundle, C. W. K., "Professor Rhine's Views about PK," *Mind*, 59 (1950): 372-379. Williams, D. C., "The Myth of Passage," *The Journal of Philosophy*, 48 (1951): 457-472. Dummet, A. E., Flew, A., "Symposium: Can an Effect Precede Its Cause?" *Proceedings of the Aristotelian Society, Supplementary Volumes*, Vol. 28 (1954): 27-62. Smart, J. J. C., "The Temporal Asymmetry of the World," *Analysis*, 14 (1954): 79-83. Flew, A., "Effects Before Their Causes?: Addenda and Corrigenda" *Analysis*, 16 (1956): 104-110. Scriven, M., "Modern Experiments in Telepathy," *The Philosophical Review*, 65 (1956): 231-253. Black, M., "Why Cannot an Effect Precede Its Cause?" *Analysis*, 16 (1956): 49-58. Flew, A., "Causal Disorder Again," *Analysis*, 17 (1957): 81-86. Pears, D. F., "The Priority of Causes," *Analysis*, 17 (1957): 54-63. Chisholm, R., Taylor, R., "Making Things to Have Happened," *Analysis*, 20 (1960): 73-78. Robertson, L. C., "The Logical and Scientific Implications of Precognition, Assuming This to Be Established Statistically from the Work of Card-Guessing Subjects," *Philosophy*, 36 (1961): 219-223. Dummet, M., "Bringing About the Past," *The Philosophical Review*, 73 (1964): 338-359. Gorovitz, S., "Leaving the Past Alone," *The Philosophical Review*, 73 (1964): 360-371. Mackie, J. L., "The Direction of Causation," *The Philosophical Review*, 75 (1966): 441-466. Meehl, P. E., "Precognitive Telepathy I: On The Possibility of Distinguishing it Experimentally from Psychokinesis," *Noûs*, 12 (1978): 235-266. Mundle, C. W. K., "Does the Concept of Precognition Make Sense?" *Philosophy and Parapsychology*, (Buffalo: Prometheus Books, 1978). Anglin, W. S., "Backwards Causation," *Analysis*, 41 (1981): 86-91. Horwich, P., *Asymmetries in Time: Problems in the Philosophy of Science*, (Cambridge: The MIT Press, 1987). Dowe, P., "Backward Causation and the Direction of Causal Processes," *Mind*, 105 (1996): 227-248. Price, H., "Backward Causation and the Direction of Causal Processes: Reply to Dowe," *Mind*, 105 (1996): 467-474. Ben-Yami, H., "The Impossibility of Backwards Causation," *The Philosophical Quarterly*, 57 (2007): 439-455. Roache, R., "Bilking the Bilking Argument," *Analysis*, 69 (2009): 605-611. An extensive philosophical literature pertaining to the implications of divine foreknowledge also exists, but it is arguable that such works are not of sufficient relevance to be referenced here.

[3] Lloyd, S., Maccone, L., Garcia-Patron, R., Giovannetti, V., Shikano, Y., Pirandola, S., Rozema, L., Darabi, A., Soudagar, Y., Shalm, L., Steinberg, A., "Closed timelike curves via postselection: theory and experimental demonstration," *arXiv*:1005.2219v1 (2010): 5 pages. Lloyd, S., Maccone, L., Garcia-Patron, R., Giovannetti, V., Shikano, Y., "Quantum mechanics of time travel through post-selected teleportation," *Physical Review D*, 84 (2010): 11 pages. Lloyd, S., Maccone, L., Garcia-Patron, R., Giovannetti, V., Shikano, Y., Pirandola, S., Rozema, L., Darabi, A., Soudagar, Y., Shalm, L., Steinberg, A., "Closed Timelike Curves via Postselection: Theory and Experimental Test of Consistency," *Physical Review Letters*, 106 (2011): 4 pages.

maximum predictive capabilities of future-viewing machines. After some preliminary concepts have been presented, the unique operational characteristics of outcome-informative future-viewing machines will be explored. An overview of related conceptual developments concerning time travel will then be provided. Once this background is in place, a conceptual framework which resolves all known time travel and time viewing confusions will be presented. Finally, a number of surprising and highly desirable implications of outcome-informative future-viewing machines will be shared for the first time.

It should be clarified at the outset that time viewing is commonplace. Since time is always required for light to reach any lens from any scene, all functioning optical systems are time viewers. More specifically, eyes, cameras, microscopes, and telescopes are *line-of-sight past viewers*. So, there can be no doubt that time viewers exist. Since line-of-sight past viewers are ubiquitous and very well-understood, it is apparent that the main conceptual intrigue to be found in the context of time viewing involves the contemplation of future-viewing systems. In this overall context, what does it mean that time viewing and time travel are reversed with respect to one another, whereby all the most troublesome aspects of time travel involve travel to the past and all the most troublesome aspects of time viewing involve viewing the future? This will turn out to be a pivotal question in the conceptual unification of time travel and time viewing.

Of course, it is reasonable to wonder whether future-viewing machines are even physically possible. Could a future-viewing machine ever actually be built? While a few of the referenced papers implicitly suggest a possible physical basis for just such a capability, an answer to this question will not be sought; instead, the present work will focus on the conceptual and logical issues which attend the assessment of such a technology, considered hypothetically.

2 Types of Future-Viewing Machines

A highly relevant concept, which has been familiar in all cultures throughout human history, is that of individuals who are somehow able to perceive future events. A notable example of this concept is found in ancient Greek mythology. Princess Cassandra, daughter of the last king of Troy, was so beautiful that even the god Apollo took notice. He offered her the power to know the future perfectly, on an understanding that she would then willingly share his bed. However, once having gained this ability, she decided to back out of the arrangement. In retribution, Apollo decreed that no one would ever believe her visions. The stage had thus been set for a powerful tragedy, for although Cassandra would later foresee the fall of her kingdom, she could not enlist any help to prevent it.[4]

The concept of such an ability is also encountered outside of mythology. However, the possibility that human minds may be capable of accessing information from the future is a problematic and murky subject that will not be

[4] Aeschylus, *Agammenon*, translated by E. D. A. Morshead, The Harvard Classics, Vol. VIII, Part 1 (New York: P. F. Collier & Son, 1909).

approached here—the primary focus throughout will be upon technologically-assisted future viewing. As such, the term *future viewer* will refer only to the concept of a future-viewing machine. A person who directs and monitors a future viewer will be referred to as its operator.

Many types of future viewers are conceivable, but various considerations lead to a unique device of interest. To understand the basics about future viewers in general, note that information about future outcomes can be either definite and correct, definite and incorrect, ambiguous and correct, or ambiguous and incorrect. Three ideas are relatively obvious, namely, that definite and correct information is the most outcome-informative kind, that ambiguous information can still be somewhat informative, as long as it is not too ambiguous, and that incorrect information of any type is never informative. To illustrate the meaning of ambiguous information, consider an assertion that one of three horses will win a race involving ten horses. If one of the three selected horses wins, such an assertion would provide an example of ambiguous and correct information which would have been somewhat informative. However, if one of the other seven horses were to win instead, the same ambiguous assertion would be incorrect and, as a result, would not have been informative. Now consider the assertion that one of ten horses will win a race involving ten horses. Assuming there will be a finisher, this maximally ambiguous assertion is correct. However, such information would be useless to anyone who might seek to gain a betting advantage. In sum, definite information about future outcomes can be either correct or incorrect, and ambiguous information about future outcomes can be correct, incorrect, or technically correct but too ambiguous to be outcome-informative.

One conceivable type of future viewer would enable its operator to see all the different ways the future could turn out (i.e., all future timelines), while being unable to reveal which timeline will be the actual future. For instance, such a machine might show all ten horses winning the race, and all ten jockeys falling off their horses, and the race being canceled, *et cetera*. Obviously, such a future viewer could only supply information that would be too ambiguous to be outcome-informative. However, for an operator who merely wishes to become informed about what future outcomes are possible, such a device would be ideal. This type of future viewer will be called an *Everett machine*.[5]

At the other extreme, one might try to imagine a future viewer which al-

[5] A major theme in popular accounts of modern physics involves how to deal with the multiple possibilities which arise in quantum mechanics (i.e., the many solutions of a given wavefunction). How should we interpret the reality underlying quantum mechanics? In 1957, Hugh Everett III proposed what he referred to as the relative state interpretation to answer this question. In the 1970s, Everett's view was popularized under the name "the many-worlds interpretation." In more recent decades, it has simply been referred to as the Everett interpretation. Apart from whether it is correct or incorrect, Everett's view holds that every quantum possibility is an actuality somewhere in a multiverse of rampant quantum bifurcation. As a result, it is natural to refer to a class of future-viewing machines able to survey every future possibility, but which cannot reveal what will happen, as Everett machines. In this context, it should be stressed that none of the results of this paper depend upon any given interpretation of quantum mechanics being correct or incorrect. Everett, H., III, "'Relative State' Formulation of Quantum Mechanics," *Reviews of Modern Physics*, 29 (1957): 454-462.

ways reveals, in every circumstance, definite and correct information about all future outcomes. Such devices will be referred to as *Cassandra machines*, after Cassandra's mythical ability.

A Cassandra machine might initially seem to be a desirable type of future viewer, until one considers what would happen if its operator were to ever dislike the future it shows. If there really were a future-viewing machine which would always, in every circumstance, provide definite and correct information about future outcomes, then its operator would not be able to circumvent any outcome it reveals. Such absolute rigidity is the unmistakable signature of Cassandra machines, and a feature of these imaginary devices which can be exploited to prove that they are not logically possible.

Dramatic examples involving foreknowledge of seemingly easily-preventable fates, which nevertheless cannot be avoided at any cost, begin to suggest that the concept of a Cassandra machine might be logically problematic. However suggestive such scenarios might be, definite information about Cassandra machines is not likely to emerge from thought experiments involving human beings; we are so unmanageably mysterious and complex, far more than any time machine or future-viewing machine could ever be. As a result, thought experiments which do not involve human operators are preferable for reaching informative conclusions. Such an exercise will be presented in the next section.

Now, since an Everett machine would show all possible outcomes, it is clear that only impossible outcomes could contradict whatever an Everett machine might show. Of course, impossible outcomes cannot occur. As a result, no scenario involving the use of an Everett machine could lead to a viewer-contradicting outcome, ensuring that Everett machines are logically possible. In contrast, as will soon be established, a Cassandra machine is not a logically possible type of future viewer. Since Cassandra machines are defined as devices which are always able to supply definite and correct information about every future outcome, regardless of circumstance, it is relatively straightforward to establish that no machine could fit such a description. This is achieved below simply by illustrating a circumstance wherein it would be impossible for any relevant instance of definite information about a future outcome to also be correct.

Cassandra machines would be truly nightmarish contraptions, so it is a fortunate fact that they are not logically possible. After the impossibility of Cassandra machines has been shown, a third type of future viewer is explained. This third type of future viewer would be able to provide definite and correct information about future outcomes under a wide range of circumstances, in the mode of a Cassandra machine, yet would automatically operate as an Everett machine (or not operate at all) whenever utilized in a circumstance that would land a pure Cassandra machine in logical hot water.

3 A Future-Viewing Thought Experiment

Imagine a computer that has mechanical control of a pointer which is able to assume 360 discrete positions against a labeled backplate. This non-networked computer is programmed to retrieve the stored output of a future-viewing machine which has been tuned to detect the future position of the same pointer, twenty seconds hence. The future viewer, the memory unit, the computer, and the mechanized pointer assembly are locked together in a secure room, under a timed lock, to ensure that the computer has sole agency over the pointer position during each run of the following experiment.

The computer will carry out various programs which specify how it is to adjust the angle of the pointer, based what it retrieves from the memory unit. Three times, t_{A}, t_{B}, and t_{C}, are ten seconds apart and in alphabetical sequence. The general experimental steps are defined as follows:

> t_{A}: At t_{A}, the t_{C} pointer angle is future-viewed. The result is stored in the memory unit as some value x, which will be retrieved by the computer once it has been activated at t_{B}. In cases of ambiguous information, x may be a conjunction of multiple values (e.g., x = 1° & 91° & 181° & 271°).
>
> t_{B}: At t_{B}, the computer is activated. It first retrieves x from the memory unit to use as input for the program to be run in that trial. The program will halt within three seconds, immediately after completion of any adjustment, if any, to the pointer angle.
>
> t_{C}: The state of the pointer at t_{C} is what the tA-stationed viewer makes an attempt to view.

Within this sequence, any of the following programs may be run:

> (P-0) At t_{A}, if the future-viewed t_{C} pointer angle is recorded as x, then at t_{B}, adjust the pointer to $x + 0°$ and halt.
>
> (P-1) At t_{A}, if the future-viewed t_{C} pointer angle is recorded as x, then at t_{B}, adjust the pointer to $x + 1°$ and halt.
>
> (P-2) At t_{A}, if the future- viewed t_{C} pointer angle is recorded as x, then at t_{B}, adjust the pointer to $x + 2°$ and halt.
>
> ...
>
> (P-359) At t_{A}, if the future-viewed t_{C} pointer angle is recorded as x, then at t_{B}, adjust the pointer to $x + 359°$ and halt.

Of course, P-360 would be equivalent to P-0, and there would also be no reason to include P-361, since it would be equivalent to P-1, and so forth. Thus, programs P-0 through P-359 are sufficient to bring about all possible integer degree adjustments to the pointer, given x as input.

Now, execution of P-0 obviously could not lead to a *viewer-contradicting outcome* (*VCO*), i.e., an outcome which would show that the future viewer had been incorrect. P-1 is where the logical puzzles begin. Assuming a pointer angle of 11° at the beginning of an experimental run involving P-1, what value will the future viewer record in the memory unit? Of course, this is a trick question: If the future viewer were to record $x = 11°$, then the computer would adjust the pointer to 12° before halting, delivering a VCO. If the future viewer were to record $x = 12°$, P-1 would deliver another VCO, for the pointer would end up at 13°. In general, if the viewer records any definite value x as the t_C pointer angle, then P-1 will adjust the pointer to rest on $x + 1°$, and a VCO will result. Of course, this means that no definite value of x could be correct with respect to the actual t_C pointer angle, since every possible definite value of x leads to a VCO. In other words, this particular setup with P-1 illustrates a "circumstance wherein it would be impossible for any relevant instance of definite information about a future outcome to also be correct." So, a Cassandra machine cannot exist, since the possibility of arranging even one such circumstance means that the definition of a Cassandra machine cannot be fulfilled by any machine whatsoever.

It has already been shown how a future viewer which presents sufficiently ambiguous information about the future can always operate in a manner which will not result in a VCO; Everett machines automatically operate in such a fashion, as they are maximally ambiguous. With the above result, it is now evident that information about future outcomes from any future viewer whatsoever must become at least somewhat ambiguous within some situations, or a VCO will result. It is vital to recognize that, if a VCO can ever result from the use of a given future-viewing technology, then a machine based on such a technology could potentially give incorrect or misleading information about future outcomes. However, a technology that might ever provide incorrect or misleading information about future outcomes could not qualify as a outcome-informative technology.

A outcome-informative future viewer will be defined as a future viewer that is able to operate in an outcome-informative mode (unlike an Everett machine), which cannot give incorrect or misleading information, and which is logically possible (unlike a Cassandra machine). This third requirement is essential because a machine which cannot exist could not be useful for any purpose. outcome-informative future viewers are therefore fully distinguishable from both Everett machines and Cassandra machines. Such devices will here be termed *foreknowledge machines.*

Engineers and physicists would additionally wish to understand the physical principles which ensure that a properly designed and manufactured future-viewing machine based on a given future-viewing technology could not systematically provide incorrect or misleading information, i.e., definite information from a foreknowledge machine that nevertheless leads to a VCO, in much the same way that the principles of optics allow biologists and astronomers to trust information from properly designed and manufactured microscopes and telescopes.[6] The development of such a theoretical understanding in the context of

[6]While scenes depicted in images can themselves be misleading (e.g., if disguise or camouflage has been used), that is a separate consideration. Many intervening optical effects may also play a role in the formation of an image, for instance, those which arise from heated air, great distance, interstellar gas and debris, fog, atmospheric effects, and lens flare—but these are separate considerations as well. Optics provides a theoretical basis for accepting that

future viewing would be central in the process of confirming that a genuine foreknowledge machine technology has been discovered. To assist the exposition, instances of definite and correct information about future outcomes received by future viewers will be referred to as *viewer foreknowledge*.

With any future-viewing machine technology, circumstances wherein only ambiguity or non-operation could allow correctness to be maintained, or at least allow a track record of correctness to be sustained, occur whenever it is not logically possible for information from a future viewer to be both definite and correct, e.g., during runs of P-1 through P-359. These scenarios will be referred to as *interference viewing scenarios*. Logical problems with definite information about future outcomes arise only within interference viewing scenarios. It is clear that there would be no similar logical limitation on either the definiteness or accuracy of information that could be gained in what will be termed *non-interference viewing scenarios*, scenarios wherein information pertaining to time-viewed outcomes will not (or could not) be used to try to alter those outcomes. Non-interference viewing scenarios must also include special cases wherein an individual or organization, once having received viewer foreknowledge pertaining to given future outcomes, will eventually help to bring those outcomes to fruition. No logical principle would prevent a future viewer from accessing viewer foreknowledge within any non-interference scenario, whereas interference viewing scenarios with respect to any given set of future outcomes could only yield ambiguous information about them, if any at all.

4 Non-Interference Viewing Scenarios and the Second-time-around Fallacy

One may surmise that all the contingencies of a given program, which may or may not cause an interference viewing scenario, have a direct effect on the minimum level of ambiguity that a future viewer will display to avoid a VCO. For example, the minimum level of ambiguity to avoid a VCO for P-1 and P-359 is 360 pointer positions, for P-90 and P-270 it is four pointer positions, and for P-180 it is two pointer positions. Of course, no ambiguity is required to avoid a VCO when running P-0, so in that case, viewer foreknowledge of the t_C pointer angle would be accessible to the future-viewing machine within the locked room. Now, imagine there is also a future-viewing machine in the next room, which may be used to observe the outcome of the experiment, but which does not pass its output to the computer. This second viewer has thus not been forced into an interference viewing scenario, so it will always provide viewer foreknowledge of the outcome of every experiment, regardless of which program is run.

Foreknowledge machines will provide viewer foreknowledge within all non-interference viewing scenarios. More generally, every type of time viewer will

properly functioning optical instruments will not provide incorrect or misleading information, because no detail in an optically-received image can correspond to something that was not in the scene and was not the result of an intervening effect.

access definite and correct information in all non-interference viewing scenarios. This generalized principle will be called the *principle of non-interference*. There are many applications of this principle. Naturally, its opposite, the *principle of interference*, states that no time viewer of any type will be able to access definite and correct information when it has been forced into an interference viewing scenario.

What are some of the applications of these principles? To begin to explore this topic, an important insight from philosophical literature about time travel is helpful: Any given events on a timeline happen only once, and not even a time traveler can alter them. Essentially, whatever happened, happened, either with or without the participation of time travelers. Failing to grasp this and imagining instead that a series of events in the past could initially occur without time travelers, and then would somehow occur again, but with a science-fiction twist, if time travelers ever decide to visit, is known among philosophers as the "second-time-around fallacy."[7] This term was coined by Nicholas J. Smith more than two decades after it was so compellingly described by Larry Dwyer:

> If we hypothesize that T pulls levers and manipulates a rocket in 1974, and travels back in time to the year 3000 B.C. then of course, even before T enters his rocket, it is true that any accurate catalogue of all the events on earth during the year 3000 B.C. would include an account of T's actions, reactions and mental processes. There is no question of the year 3000 B.C. occurring more than once.[8]

Three years later, David Lewis also described the second-time-around fallacy in his classic 1976 paper, "The Paradoxes of Time Travel." Here is his description, presented in terms of a time travel puzzle that needs no introduction, the so-called grandfather paradox:

> We may be tempted to speak of the "original" 1921 that lies in Tim's personal past, many years before his birth, in which Grandfather lived; and of the "new" 1921 in which Tim now finds himself waiting in ambush to kill Grandfather. But if we do speak so, we merely confer two names on one thing.[9]

[7]Smith, N. J. J., "Bananas Enough for Time Travel?" British Journal of the *Philosophy of Science*, 48 (1997): 363-389.

[8]Dwyer, L., "Time Travel and Changing the Past," *Philosophical Studies: An International Journal for Philosophy in the Analytic Tradition*, 27 (1975): 341-350.

[9]Lewis, D., "The Paradoxes of Time Travel," *American Philosophical Quarterly*, 13 (1976): 145-152. In this context, science-fiction author, Larry Niven, presented a most delightfully paradoxical version of the grandfather paradox in his 1971 essay, "The Theory and Practice of Time Travel." "The Grandfather Paradox is basic to any discussion of time travel. It runs as follows: At the age of eighty your grandfather invents a time machine. You hate the old man, so you steal the machine and take it sixty years back into the past and kill him. How can they suspect you? But you've killed him before he can meet your grandmother. Thus you were never born. He didn't get a chance to build the time machine either. But then you can't have killed him. Thus he may sire your father, who may sire you. Later there will be a time machine..." Niven also poetically quipped: "With a Grandfather Paradox operating, the effect, coming before the cause, may cause the cause never to come into effect, with results

The past cannot be altered or reset, so no logical reason could prevent any instance of past viewing from taking the form of definite and correct information. In other words, past viewing is always automatically conducted within non-interference viewing scenarios; there is no way to force a past viewer into an interference viewing scenario. As will soon be established, this would hold even if time travel were available. Since past viewing is the only way we see anything, then even if the world were filled with time travel, it would never become ephemeral and uncertain. As opposed to so many confused (although admittedly entertaining) cinematic treatments, pastward time travel could never cause people to slowly disappear or make photographs of relatives fade away. Recognizing that the past cannot be changed goes hand-in-hand with the notion that it is impossible to cause any sort of a paradox with time travel, a conclusion that will be fully established in the next section.

So, it should be clear that a time traveler cannot change anything in the past—even to the extent of disturbing a single 1921 electron. Time travelers can only participate in past events, just as they happened, if the manner in which they happened involved the participation of time travelers. This also applies to the kind of role we play in present and future events; all times are equivalent in this respect. On this topic, Lewis provided the following insightful observation:

> You cannot change a present or future event from what it was originally to what it is after you change it. What you *can* do is to change the present or the future from the unactualized way they would have been without some action of yours to the way they actually are. But that is not an actual change: not a difference between two successive actualities.[10]

Past outcomes are fixed; no technology could bring about "a difference between two successive actualities" in order to change past outcomes.[11] As a result,

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which are not even self-consistent." Niven, L., "The Theory and Practice of Time Travel," *All the Myriad Ways*, (New York: Ballantine Books, 1975).

[10]Lewis, D., "The Paradoxes of Time Travel," *American Philosophical Quarterly*, 13 (1976): 145-152.

[11]One might interpret current retrocausal quantum signaling experiments, if successful, to represent a challenge to the point made in the text. While such experimental efforts seek to demonstrate a later cause having an earlier effect, usually due to quantum entanglement between non-delayed photons and photons delayed via miles of fiber-optic cable, they certainly could not involve "a difference between two successive actualities." If such experiments prove successful, they would only serve to support the point being made in the text; they would show the causal participation of a future (or present) event in a present (or past) outcome. Scientists have long considered retrocausality to be a legitimate physical possibility which might also be an essential feature of physical laws. Feynman, R., Wheeler, J. A., "Interaction with the Absorber as the Mechanism of Radiation," *Reviews of Modern Physics*, 17 (1945): 157-181. Feynman, R., Wheeler, J. A., "Classical Electrodynamics in Terms of Direct Interparticle Action," *Reviews of Modern Physics*, 21 (1949): 425-433. Cramer, J. G., "The Transactional Interpretation of Quantum Mechanics," *Reviews of Modern Physics*, 58 (1986): 647-687. Cramer, J. G., "An Overview of the Transactional Interpretation of Quantum Mechanics," *International Journal of Theoretical Physics*, 27 (1988): 227-236. Dobyns, Y. H., "Retrocausation, Consistency, and the Bilking Paradox," *AIP Conf. Proc.*, 1408 (2011): 235-

all past viewers must operate exclusively in non-interference viewing scenarios. Soon, after more conceptual background has been presented, an effort will be made to force a line-of-sight past viewer into an interference viewing scenario. However, the understanding to be gained next will serve to show that this cannot be achieved.

5 Quantum Mechanics Associated with Pastward Time Travel and Future Viewers

In an exploration of the manner in which time travel paradoxes may be eliminated, a pursuit which also reveals many insights related to the behavior of foreknowledge machines, it is useful to begin by mentioning the Novikov self-consistency principle, named after the Russian physicist Igor Novikov. This principle was expressed in the 1990 paper, "Cauchy problem in spacetimes with closed time-like curves,"[12] by Novikov and physicists John Friedman, Michael Morris, Fernando Echeverria, Gunnar Klinkhammer, Kip Thorne, and Ulvi Yurtsever. *Closed timelike curves* (*CTCs*) are efficiently described as, "trajectories in spacetime that effectively travel backwards in time: a test particle following a CTC can in principle interact with its former self in the past."[13]

The self-consistency principle bears Novikov's name because he advanced it well over a decade earlier at physics conferences and in a Russian book he co-authored with Yakov Zel'dovich.[14] The following quotation from the 1990 paper, with its original italics, provides its final formulation as well as information about Novikov's initial conceptual motivation:

> Some years ago... Novikov... briefly considered the possibility that... [CTCs] might exist and argued that they cannot entail this type of causality violation... [i.e., changes to the past]: Events on a CTC are already guaranteed to be self-consistent, Novikov argued; they influence each other around the closed curve in a self-adjusted, cyclical, self-consistent way. The other authors recently have arrived at the same viewpoint.

254. Radin, D. I., "Predicting the Unpredictable: 75 Years of Experimental Evidence," *AIP Conf. Proc.*, 1408 (2011): 204-217.

[12]Echeverria, F., Friedman, J., Klinkhammer, G., Morris, M. S., Novikov, I. D., Thorne, K. S., Yurtsever, U., "Cauchy problem in spacetimes with closed timelike curves," *Physical Review D*, 42 (1990): 1915-1930.

[13]Lloyd, S., Maccone, L., Garcia-Patron, R., Giovannetti, V., Shikano, Y., Pirandola, S., Rozema, L., Darabi, A., Soudagar, Y., Shalm, L., Steinberg, A., "Closed timelike curves via postselection: theory and experimental demonstration," *arXiv*:1005.2219v1 (2010): 5 pages.

[14]Novikov, I. D., Zel'dovich, Y. B., *Stroeniye i Evolyutsia Vselennoi* (Moscow: Nauka, 1975). The endnote in "Cauchy problem in spacetimes with closed timelike curves," which contains the above reference includes the following curious comment which reveals a certain political sensitivity surrounding the physics of CTCs in the early '80s: "Note that in the English edition of the latter reference [*Relativistic Astrophysics, Vol. 2, The Structure and Evolution of the Universe* (University of Chicago Press, Chicago, 1983), bottom of page 637 and top of page 638] the text was changed without Novikov's agreement to say that CTC's cannot occur."

> We shall embody this viewpoint in a *principle of self-consistency*, which states that *the only solutions to the laws of physics that can occur locally in the real Universe are those which are globally self-consistent.* This principle allows one to build a local solution to the equations of physics only if that local solution can be extended to be part of a (not necessarily unique) global solution...[15]

In this context, 'global' refers to all of space and time. The term CTC has been familiar to physicists since Kurt Gödel's famous 1949 time travel result. Gödel's paper proved that CTCs which would enable travel to the past automatically emerge within solutions of the equations of general relativity, as long as one posits a rotating universe. Nearly sixty-five years ago, Gödel was able to mathematically establish that, "it is theoretically possible in these worlds to travel into the past, or otherwise influence the past."[16] While there is no evidence that our universe is rotating, the conceptual cat had nevertheless been let out of the bag—theorists have understood for two generations that pastward time travel is compatible with general relativity.

Disregarding Novikov's self-consistency principle, one may still idly imagine a person going back in time to break the chain of his or her own lineage to bring about a dreaded time travel paradox. However, in reality, the idea that it might ever be possible to rearrange natural phenomena in any way that could "trick" nature into an actual paradox is absurd. No serious thinker believes genuine physical paradoxes are at all possible, either via pastward time travel or by any other means. Accordingly, many have concluded that pastward time travel must not be possible, on the assumption that such a form of travel could allow paradoxes to be set up. However, the conclusion, "if nature were to allow pastward time travel at all, then paradoxes could be set up," does not follow from a series of stories which can only serve to establish that one may choose to imagine, among other choices, that pastward time travel could lead to paradoxes. A physical mechanism that would make it impossible for anyone to embark on time trips which would lead to paradox, but which would also allow consistent time trips to proceed, would rule out any possibility of paradox without ruling out pastward time travel. In order to accept that opening and traversing a CTC to the past may be a genuine technological possibility, it is necessary to believe that such a mechanism may exist. So, ultimately, efforts to discover principles which might constitute such a mechanism are an aid to understanding whether pastward time travel may really be possible.

However, there is potentially a much more direct way to evaluate its possibility. An inventor would not have to concern himself with questions of paradox at all; a single journey to the past would settle the matter entirely. Since paradoxes are every bit as impossible as round squares, there is no reason for an inventor to worry about the potential of causing them.

[15] Echeverria, F., Friedman, J., Klinkhammer, G., Morris, M. S., Novikov, I. D., Thorne, K. S., Yurtsever, U., "Cauchy problem in spacetimes with closed timelike curves," *Physical Review D*, 42 (1990): 1915-1930.

[16] Gödel, K., "An Example of a New Type of Cosmological Solutions of Einstein's Field Equations of Gravitation," *Reviews of Modern Physics*, 21 (1949): 447-450.

So, if there are any time travelers who know much about us, they surely derive amusement from the quaint 20th-century misconception, which still holds sway in our century, that traveling to the past might ever cause some kind of paradox. For people of our era who have never seen a time machine, however, a question mark still looms over whether pastward time travel can ever be accomplished, so a proof which assures us that it could not lead to paradox would be very helpful indeed, and would embolden inventors to press forward (or pastward, as the case may be). The search for such a proof and its attendant concepts was arguably initiated by science fiction writers, then was greatly advanced by philosophers, and finally, for all intents and purposes, has recently been ended by physicists.[17]

The many papers referenced in the first endnote represent the most notable examples from the first twenty-eight years of philosophical writings on time travel. In the earliest of these works, attempts were made to argue that time travel is not logically possible, due to various supposed inconsistencies and paradoxes.[18] The field then began to lean toward the opposite viewpoint. With

[17]In order to trace, as far back as possible, the search for a proof that time travel cannot lead to paradoxes, one must begin by reading early science fiction. While many stories allow paradoxes to occur for dramatic effect, other works invented mysterious or ironic ways that nature would respond in order to avoid or repair them. To reveal specifics could potentially spoil hours of fun. Nahin, P. J., *Time Machines: Time Travel in Physics, Metaphysics and Science Fiction* (New York: Springer-Verlag and AIP Press, 1999). Also see Niven's insightful essay on time travel geared toward the science-fiction author: Niven, L., "The Theory and Practice of Time Travel," *All the Myriad Ways*, (New York: Ballantine Books, 1975). As noted throughout the paper, philosophers also eventually got into the act and made a great deal of progress. Most notably, they identified the second-time-around fallacy. Berger, G., "The Conceptual Possibility of Time Travel," *The British Journal of the Philosophy of Science*, 19 (1968): 152-155. Dwyer, L., "Time Travel and Changing the Past," *Philosophical Studies: An International Journal for Philosophy in the Analytic Tradition*, 27 (1975): 341-350. Thom, P., "Time-Travel and Non-Fatal Suicide," *Philosophical Studies: An International Journal for Philosophy in the Analytic Tradition*, 27 (1975): 211-216. Lewis, D., "The Paradoxes of Time Travel," *American Philosophical Quarterly*, 13 (1976): 145-152. Dwyer, L. "How to affect, but not change, the past," *The Southern Journal of Philosophy*, 15 (1977): 383-385. Casati, R., "That Useless Time Machine," *Philosophy*, 76 (2001): 581-583. Goddu, G. C., "A Useful Time Machine," *Philosophy*, 77 (2002): 281-282. Finally, a team of physicists recently established why time travel cannot lead to paradoxes. Lloyd, S., Maccone, L., Garcia-Patron, R., Giovannetti, V., Shikano, Y., Pirandola, S., Rozema, L., Darabi, A., Soudagar, Y., Shalm, L., Steinberg, A., "Closed timelike curves via postselection: theory and experimental demonstration," *arXiv*:1005.2219v1 (2010): 5 pages. Lloyd, S., Maccone, L., Garcia-Patron, R., Giovannetti, V., Shikano, Y., "Quantum mechanics of time travel through post-selected teleportation," *Physical Review D*, 84 (2010): 11 pages. Lloyd, S., Maccone, L., Garcia-Patron, R., Giovannetti, V., Shikano, Y., Pirandola, S., Rozema, L., Darabi, A., Soudagar, Y., Shalm, L., Steinberg, A., "Closed Timelike Curves via Postselection: Theory and Experimental Test of Consistency," *Physical Review Letters*, 106 (2011): 4 pages.

[18]Donald Williams' often-cited article argues against the conceptual possibility of time travel. Williams, D. C., "The Myth of Passage," *The Journal of Philosophy*, 48 (1951): 457-472. Fred Dretske's 1962 article also raises issues regarding its conceptual possibility. Dretske, F. I., "Moving Backward in Time," *The Philosophical Review*, 71 (1962): 94-98. While Hilary Putnam argued in favor of its conceptual possibility in his 1962 article, "It Ain't Necessarily So," he also tantalizingly remarked that, "[i]n the last few years I have been amused and irritated by the spate of articles proving that time travel is a 'conceptual impossibility.'" Unfortunately, he did not cite any member of that spate. While it is unclear which articles Putnam had in mind, he may have been thinking of some of the earlier works cited in the

difficult questions as to its physical possibility set off to the side, philosophers began pointing out that the conceivability of consistent forms of pastward time travel at least establishes that it is a logical possibility.[19]

From that moment in the history of conceptual development forward, philosophers began discussing the imagined implications of assuming that time travel is physically possible and yet cannot be used to produce paradoxes. The contributions of these later papers fall into at least two broad categories. First and foremost, the nature of self-consistent time travel received clarification. The seminal papers which identified, established, and elaborated the second-time-around fallacy fall under this classification.[20] These contributions were very important among the developments of the 1970s which have crystallized into the present understanding.

Still other papers take the idea of an unalterable past for granted and attempt to understand the full implications of this in the context of time travel. However, as will be explained, many of these papers discuss the strange coincidences that were mistakenly assumed would have to occur in order for nature to be able to protect itself from our temporal manipulations.[21] The current

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second endnote which argue against the possibility of backward causation, as they may be construed as implicitly arguing against the conceptual possibility of time travel. Putnam, H., "It Ain't Necessarily So," *The Journal of Philosophy*, Vol. 59, No. 22, *American Philosophical Association Eastern Division: Symposium Papers to be Presented at the Fifty-Ninth Annual Meeting*, New York City, December 27-29, 1962 (1962), 658-671.

[19]Mayo, B., "Objects, Events, and Complementarity," *The Philosophical Review*, 70 (1961): 340-361. Putnam, H., "It Ain't Necessarily So," *The Journal of Philosophy*, Vol. 59, No. 22, *American Philosophical Association Eastern Division: Symposium Papers to be Presented at the Fifty-Ninth Annual Meeting*, New York City, December 27-29, 1962 (1962), 658-671. Philosopher J. J. C. Smart concluded, "we can concede the conceptual possibility of time travel." Smart, J. J. C., "Is Time Travel Possible?" *The Journal of Philosophy*, 60 (1963): 237-241. Berger, G., "The Conceptual Possibility of Time Travel," *The British Journal of the Philosophy of Science*, 19 (1968): 152-155. Meiland, J. W., "A Two-Dimensional Passage Model of Time for Time Travel," *Philosophical Studies: An International Journal for Philosophy in the Analytic Tradition*, 26 (1974): 153-173. Horwich, P., "On Some Alleged Paradoxes of Time Travel," *The Journal of Philosophy*, Vol. 72, No. 14, Time, Cause, and Evidence (1975): 432-444. Dwyer, L., "Time Travel and Changing the Past," *Philosophical Studies: An International Journal for Philosophy in the Analytic Tradition*, 27 (1975): 341-350. Lewis, D., "The Paradoxes of Time Travel," *American Philosophical Quarterly*, 13 (1976): 145-152. Weingard, R., "General Relativity and the Conceivability of Time Travel," *Philosophy of Science*, 46 (1979): 328-332.

[20]Berger, G., "The Conceptual Possibility of Time Travel," *The British Journal of the Philosophy of Science*, 19 (1968): 152-155. Dwyer, L., "Time Travel and Changing the Past," *Philosophical Studies: An International Journal for Philosophy in the Analytic Tradition*, 27 (1975): 341-350. Thom, P., "Time-Travel and Non-Fatal Suicide," *Philosophical Studies: An International Journal for Philosophy in the Analytic Tradition*, 27 (1975): 211-216. Lewis, D., "The Paradoxes of Time Travel," *American Philosophical Quarterly*, 13 (1976): 145-152. Dwyer, L. "How to affect, but not change, the past," *The Southern Journal of Philosophy*, 15 (1977): 383-385. Casati, R., "That Useless Time Machine," *Philosophy*, 76 (2001): 581-583. Goddu, G. C., "A Useful Time Machine," *Philosophy*, 77 (2002): 281-282.

[21]Earman, J., "Implications of Causal Propagation Outside the Null-Cone," *Australasian Journal of Philosophy*, 50 (1972): 222-237. Lewis, D., "The Paradoxes of Time Travel," *American Philosophical Quarterly*, 13 (1976): 145-152. Horwich, P., *Asymmetries in Time: Problems in the Philosophy of Science*, (Cambridge: The MIT Press, 1987). Maudlin, T., "Time-Travel and Topology," *PSA: Proceedings of the Biennial Meeting of the Philosophy of*

state-of-the-art thinking to be detailed soon, however, indicates that protective coincidences would essentially be a non-issue in the context of actual pastward time travel, if there is or will ever be such a context.

For instance, papers like "Bananas Enough for Time Travel?" accept the second-time-around fallacy and go on to discuss the idea that coincidences might prevent "bilking," a term widely used by philosophers as a shorthand for would-be paradoxical tomfoolery.[22] Lewis identified coincidences, such as slipping on a banana peel right before a bilking attempt, as a catch-all means whereby bilking could be prevented, were pastward time travel ever practiced. Works which discuss coincidences as a central consideration generally argue that the inordinate number that would supposedly be required may permit the conclusion that pastward time travel is not likely to be feasible, but cannot justify an argument that it must be impossible.[23]

The latest viewpoint, however, shows that coincidences are not of any special importance in the context of time travel. While apparent coincidences could occur to prevent a bilking incident, just as rarely as they might occur to prevent anything else, there is no reason to posit that coincidences would or must occur with greater than normal frequency in spacetime regions around CTCs. Instead, it is now understood that bilking would always automatically be prevented at the source: Any attempt to open a CTC to the past which would have resulted in bilking will be unsuccessful.[24]

Science Association, Vol. 1990, Volume One: Contributed Papers (1990): 303-315. Smith, N. J. J., "Bananas Enough for Time Travel?" *British Journal of the Philosophy of Science*, 48 (1997): 363-389. Smith, N. J. J., "The problems of backward time travel," Endeavor, 22 (1998): 156-158. Ismael, J., "Closed Causal Loops and the Bilking Argument," *Synthese*, 136 (2003): 305-320.

[22]Smith, N. J. J., "Bananas Enough for Time Travel?" *British Journal of the Philosophy of Science*, 48 (1997): 363-389.

[23]Maudlin, T., "Time-Travel and Topology," *PSA: Proceedings of the Biennial Meeting of the Philosophy of Science Association*, Vol. 1990, Volume One: Contributed Papers (1990): 303-315. Smith, N. J. J., "Bananas Enough for Time Travel?" *British Journal of the Philosophy of Science*, 48 (1997): 363-389. Sider, T., "Time Travel, Coincidences and Counterfactuals," *Philosophical Studies: An International Journal for Philosophy in the Analytic Tradition*, 110 (2002): 115-138. Ismael, J., "Closed Causal Loops and the Bilking Argument," *Synthese*, 136 (2003): 305-320.

[24]Lloyd, S., Maccone, L., Garcia-Patron, R., Giovannetti, V., Shikano, Y., Pirandola, S., Rozema, L., Darabi, A., Soudagar, Y., Shalm, L., Steinberg, A., "Closed timelike curves via postselection: theory and experimental demonstration," *arXiv*:1005.2219v1 (2010): 5 pages. Lloyd, S., Maccone, L., Garcia-Patron, R., Giovannetti, V., Shikano, Y., "Quantum mechanics of time travel through post-selected teleportation," *Physical Review D*, 84 (2010): 11 pages. Lloyd, S., Maccone, L., Garcia-Patron, R., Giovannetti, V., Shikano, Y., Pirandola, S., Rozema, L., Darabi, A., Soudagar, Y., Shalm, L., Steinberg, A., "Closed Timelike Curves via Postselection: Theory and Experimental Test of Consistency," *Physical Review Letters*, 106 (2011): 4 pages. Here is what, "[a]ny attempt to open a CTC to the past which would have resulted in bilking will be unsuccessful," would mean for Tim's wish to pay his grandfather a deadly visit. Let's grant that a CTC opens to allow Tim to set foot in 1921. During Tim's visit, even if it were to appear that a coincidence has miraculously intervened in order to prevent grand-patricide, such a happening would neither be miraculous nor coincidental. Instead, such a happening had already served to allow the CTC to open, which would not have otherwise opened. In all likelihood, however, since wayward banana peels and jammed guns are so rare, it is overwhelmingly likely that Tim would simply be unable to open a CTC

This is an astounding result which has revolutionized the understanding of how pastward time travel can be kept logically consistent within a non-bifurcating temporal ontology.[25] To understand this result, a brief detour into the work of Lloyd *et al.* will be required. Seth Lloyd, of MIT, is a leading expert in quantum engineering and quantum information. His team explored a possible analog of time travel within the framework of "postselected quantum teleportation."[26] Quantum teleportation allows for quantum information to be transferred from one quantum system and embodied in a receiving quantum system. Their essential idea was to encode the logical features of a bilking attempt into measurable quantities in a specially-designed experiment involving postselected quantum teleportation, and then to observe what happens. This innovation allowed them to physically simulate postselected CTCs (P-CTCs), in order to experimentally explore whether nature would allow bilking within a model of time travel based on P-CTCs. Here is their experiment, in their own words:

> We present an experiment to simulate how the grandfather paradox might develop in a P-CTC: the postselected results are indistinguishable from what would happen when a photon is sent a few billionths of a second back in time to try to "kill" its former self.[27]

For further insight into what they accomplished by proposing this theoretical framework and obtaining the related experimental results, here are two additional quotations from the same article:

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to 1921, until he has a change of heart. However, even if he were to eventually decide that he only wants to see his grandfather from afar, the second-time-around fallacy would have the final say: If Tim never took part in any of the happenings of 1921, it would simply be off limits to him. Of course, this is all enforced by the fact that a CTC to 1921 will never open for him to traverse. If he was never part of that year, a CTC to 1921 might open for others, even in situations where Tim is standing close to the time portal platform, but a CTC to 1921 will never open in any circumstance which will lead to Tim traversing it.

[25] David Deutsch proposed in 1991, and in 1994 with Michael Lockwood, that time travel could be kept logically consistent if the Everett interpretation of quantum mechanics (a bifurcating temporal ontology) were true, for time travel would consist of travel to other universes. John Abbruzzese discussed some problems he perceived with this model of time travel in a short 2001 article. More decisively, in 2004, a physicist with an ironic last name, Allen Everett, calculated that wormhole time travel to other times within a multiverse context would result in, "different pieces [of the unfortunate would-be time traveler] winding up in different 'worlds.'" In his 2012 article on the same topic, Nikk Effingham explored whether multiverse time travel would even count as time travel, and referred to Everett's 2004 result as the "Slicing Thesis." Deutsch, D., "Quantum mechanics near closed timelike lines," *Physical Review D*, 44 (1991): 3197-3217. Deutsch, D., Lockwood, M., "The Quantum Physics of Time Travel," Scientific American, 270 (1994): 68-74. Abbruzzese, J., "On using the multiverse to avoid the paradoxes of time travel," *Analysis*, 61 (2001): 36-38. Everett, A., "Time Travel Paradoxes, Path Integrals, and the Many Worlds Interpretation of Quantum Mechanics," *Physical Review D*, 69 (2004): 35 pages. Effingham, N., "An Unwelcome Consequence of the Multiverse Thesis," *Synthese*, 184 (2012): 375-386.

[26] Lloyd, S., Maccone, L., Garcia-Patron, R., Giovannetti, V., Shikano, Y., Pirandola, S., Rozema, L., Darabi, A., Soudagar, Y., Shalm, L., Steinberg, A., "Closed Timelike Curves via Postselection: Theory and Experimental Test of Consistency," *Physical Review Letters*, 106 (2011): 4 pages.

[27] Ibid.

> The P-CTC... starts from two systems prepared in a maximally entangled state $|\Psi>$..., and ends by projecting them into the same state $<\Psi|$... Probabilities for events in the presence of a P-CTC are obtained by using ordinary quantum mechanics to calculate the *conditional* probabilities of the events given that a measurement on the final part of the CTC yields the state $|\Psi>$. The probabilities for events in a P-CTC thus depend on the past and the future.
>
> If the probability for the outcome $|\Psi>$ is zero, then the P-CTC cannot occur: our mechanism embodies in a natural way the Novikov principle... that only logically self-consistent events occur in the universe....
>
> These probe qubits measure the state of the polarization qubit before and after the quantum gun is "fired." When the postselection succeeds (which simulates the time travel occurring), the state of the qubits is measured. If they are equal (00 or 11) the gun has failed to flip the polarization: the photon "survives," otherwise (01 or 10) the photon has "killed" its past self.
>
> The state of the probe qubits, conditioned on the post-selection succeeding, was measured for different values of ϑ... [from the relevant diagram in the article, ϑ is the "Quantum Gun Angle"]. The probes are never 01 or 10, which shows that "time travel cannot happen" unless the gun misfires, leaving the polarization qubit unchanged and the probes in 00 or 11. Namely, suicidal photons in a CTC obey the Novikov principle: they cannot kill their former selves.[28]

So, their P-CTC model automatically explains why bilking would be impossible. Attempts to open a CTC into the past would not just depend on the technological capability of doing so, such attempts would also depend, on a case by case basis, upon all of the resultant effects of doing so. Assuming a working time machine, if a given attempt to open and traverse a CTC would have led to bilking, that attempt will fail; a CTC will not open. On the other hand, using the same time machine, if another attempt to open and traverse a CTC will not lead to bilking, that CTC will open.

This makes sense within a postselected model of time travel, i.e., a "self-adjusted, cyclical, self-consistent" model of time travel; the CTC to the past defines the initial leg of a would-be cycle, and the fact that all the effects of a given CTC-opening would already be present when the attempt to open that CTC is made, defines the return leg. Only self-consistent cycles would be permitted in the instantaneous postselection process which attends every attempt to open a CTC, so even cases of unintentional bilking would be ruled out. An easy way to encapsulate all of these ideas is to note that the personal future of time travelers who are traveling into the past must already be part of the past whenever they might attempt to begin their journey. This means that they would not be able to do just anything on a trip to the past, they could only do

[28] Ibid.

precisely what occurred in the past. So, in some sense, since every trip back will have already happened by the time it is attempted, only those attempts to take trips into the past that were successful will be successful. Trips that were not taken, can never be taken, and trips that bilk could not have been taken, so were not taken, and so can never be taken.

This cyclical view of time travel may seem, at first, like a sleight-of-hand trick. However, consideration of time travel in terms of the insights supporting the second-time-around fallacy lead directly to this same view.

An important question was posed in the introduction: What does it mean that time viewing and time travel are reversed with respect to one another, whereby all the most troublesome aspects of time travel involve travel to the past and all the most troublesome aspects of time viewing involve viewing the future? It turns out that time viewing is a special case of time travel, for note that traveling back in time with information about the future could yield the same information as viewing the future. The answer to this question is that the "most troublesome aspects" of time travel and the "most troublesome aspects" of time viewing, which initially appear separate, are actually the same. This is clarified upon consideration of a cyclical view of future viewing. Viewer foreknowledge can only occur when its reception cannot lead to a VCO, and every attempt to view the future under an interference viewing scenario, at most, could only yield ambiguous information, such as one would expect from an Everett machine. So, anything that the logical coherence of events leading to a given future demands that we must not know before those events transpire will simply be off limits to us, both because time travelers will not be able to bring such information back to us (or send it through a CTC), and also because, in such cases, future-viewing machines will not be able to provide us with viewer foreknowledge. So, essentially identical cyclical analyses serve to explain why both time travel and time viewing are bilk-proof. This series of insights will be referred to as *view-travel unification.*

A surprising application of view-travel unification provides the solution to the following modified experiment which will pit the principle of non-interference against the principle of interference in a most dramatic way. Telescopes are line-of-sight past viewers, and the same is true of radio telescopes (i.e., parabolic dish radio receivers). With this in mind, consider a new pointer position experiment which initially appears to be equivalent to the original pointer position experiment, in which a radio telescope will be used instead of a future viewer. The procedure which makes this a seemingly equivalent experiment is that the radio telescope and its corresponding memory unit will be attached to the computer which controls the pointer assembly, and all of this equipment will be set up within a time machine spaceship which will automatically take itself into the past to give it enough time to travel through space to the transmission point one year before, one light-year away. Assuming the spaceship is able to complete a one light-year journey in ten years, the time machine aspect of the spaceship will be programmed to bring the entire assembly a little more than eleven years into the past; this gives it ample time to complete its long space journey toward the transmission point. The time labels $t_{\mathrm{A'}}$, $t_{\mathrm{B'}}$, and $t_{\mathrm{C'}}$ will be used for this modified experiment—in this case arranged alphabetically in sequence with respect to the "personal time" of the spaceship, rather than in terms of calendar time, as before—which is to be carried out in the following manner:

> $t_{A'}$: At $t_{A'}$, the $t_{C'}$ pointer angle is received in a radio transmission which originated one light-year away. The result is stored in the memory unit as value y, which will be retrieved by the computer upon activation at $t_{B'}$. In cases of ambiguous information, y may be a conjunction of multiple values (e.g., $x = 18°$ & $108°$ & $198°$ & $288°$).
>
> $t_{B'}$: A short while after the spaceship has arrived at its destination, one light-year away from Sol, and has decelerated until its relative velocity is null with respect to Sol (in order to ensure that a distant evaluation of timing can be given a straightforward meaning), the computer is activated precisely one year and ten seconds (in terms of calendar time) before $t_{A'}$, i.e., at $t_{B'}$. Upon activation, the computer retrieves y from the memory unit, and a given program is executed by the computer using y as input. The program halts within three seconds, immediately after completion of any adjustment to the pointer angle.
>
> $t_{C'}$: Ten seconds after $t_{B'}$ the state of the pointer at $t_{C'}$ is transmitted to Sol for the $t_{A'}$-stationed radio telescope within the considerably "younger" version of the time machine spaceship to receive.

As above, many different programs may be specified:

> (P-0') At $t_{A'}$, if the $t_{C'}$ pointer angle is received as y, then at $t_{B'}$, adjust the pointer to $y + 0°$ and halt. (P-1')
>
> At $t_{A'}$, if the $t_{C'}$ pointer angle is received as y, then at $t_{B'}$, adjust the pointer to $y + 1°$ and halt. (P-2')
>
> At $t_{A'}$, if the $t_{C'}$ pointer angle is received as y, then at $t_{B'}$, adjust the pointer to $y + 2°$ and halt.
>
> ...
>
> (P-359') At $t_{A'}$, if the $t_{C'}$ pointer angle is received as y, then at $t_{B'}$, adjust the pointer to $y + 359°$ and halt.

This complicated description represents a case where a line-of-sight past viewer can seemingly be made to stand in for a future viewer. If this truly could be done, then the idea that all past-viewing occurs only within non-interference viewing scenarios would have to be abandoned. At first it might appear that, during a run of P-1' through P-359', the radio receiver would be forced into an interference viewing scenario, in which case the principle of interference would suggest that the only way a VCO could be avoided would be for the radio receiver to pick up ambiguous information about the outcome of the experiment. As promised, the principle of interference will now be pit against the principle of non-interference. This is accomplished by imagining that an identically-constructed radio telescope is positioned alongside the spaceship time machine at $t_{A'}$. This second radio telescope, since it does not pass any information to the computer within the time machine spaceship, would be in a non-interference viewing scenario with respect to the outcome of the experiment. Thus, the principle of non-interference indicates that this second radio telescope will receive definite and correct information about the outcome of the experiment. As a result, if both principles are right, it seems that two identically-constructed radio telescopes, which have been positioned side-by-side, would have to receive the same signal differently. Such a phenomenon is surely impossible, so it initially appears that this thought experiment may have uncovered a conceptual problem with these principles. However, the postselected, self-adjusting, cyclical, self-consistent model of pastward time travel at the basis of view-travel unification means that a time machine cannot be used to make a line-of-sight past viewer stand in for a future viewer in such an experiment, because a CTC will only open up if the program to be run is P-0'. The entire false dilemma has thus been sidestepped. A VCO cannot occur for line-of-sight past viewers, which indeed operate exclusively in non-interference viewing scenarios.

Conceptually, at least, there is another variety of past viewer, the *chronovisor*.[29] A chronovisor is a machine imagined to have the ability to display any scene its operator selects from the past, i.e., a *non-line-of-sight past viewer*. If all past viewers operate exclusively in non-interference viewing scenarios, a properly functioning chronovisor should always be able to provide definite and correct information about any of the past events its operator has adjusted the chronovisor's controls to receive. As in the radio telescope case, this must even be true if the operator of a chronovisor were also able to employ time travel: If she sees into the past with a chronovisor, she will either see herself attending a given event by way of her time machine, or not. An imagined third possibility, wherein she does not see herself participating in the event "the first time around," and afterwards decides to use her time machine to participate in it "the second time around," is an absurdity which has already been dismissed.

More conceptual work, however, is required to establish that chronovisors always operate exclusively in non-interference viewing scenarios, even if pastward

[29]Krassa, P., *Dein Schicksal ist vorherbestimmt: Pater Ernettis Zeitmaschine und das Geheimnis der Akasha-Chronik* (Herbig: München, 1997). Three years later, Krassa's book was translated from the original German. Krassa, P., *Father Ernetti's Chronovisor: The Creation and Disappearance of the World's First Time Machine*, (Boca Raton: New Paradigm Books, 2000). The story it tells is that a machine which could view and hear any scene from the past was developed in the 1950s, by a team which eventually included Enrico Fermi, following an accidental discovery with audio equipment made by Father Pellegrino Ernetti and Father Agostino Gemelli on September 15th, 1952. Even if such a machine did exist (which would mean that very advanced versions of it exist today), given that 'chronovisor' is not a household name, one should not expect all the details surrounding this story to amount to a fully convincing case. Whether these alleged developments are part of the secret history of technology or not, 'chronovisor' is a compelling and efficient term to use when discussing the concept of non-line-of-sight past viewers. For interested readers who might wish to cross-reference the information contained in Krassa's book, two other book-length works on the chronovisor story are also available: Teodorani, M., *Il Cronovisore: Sogno del futuro o esperimenti reali?* (Diegaro di Cesena: Macro Edizioni, 2006). Brune, F., *Das Geheimnis des Pater Ernetti: Die Zeitmachine im Vatikan*, (Saarbrücken: Hesper Verlag, 2010).

time travel is also available. The case where a time traveler uses a chronovisor to watch her own journey to the past which is also in her personal past is obviously non-problematic. On the other hand, if a time traveler were to use a chronovisor to view a journey she has yet to take, one might wonder whether the chronovisor could potentially be forced into an interference viewing scenario. Just as in the case of line-of-sight past viewers, view-travel unification also prevents this possibility for chronovisors to the extent that a time traveler using a properly designed and functioning chronovisor will only receive definite and correct information about past events, even past events in which she has yet to participate: A CTC will not open to allow any trip to the past inconsistent with what has been, will, or could be chronovised.

This requirement forces non-contradiction, but at first it seems to reopen the door to bilking. After using her chronovisor to view her upcoming time trip, one might think that she now has an opportunity to go back in time and choose to zig, even though she chronovised that she will go back and zag. Yet, if she indeed zagged at that moment, being a time traveler, she knows that the required CTC will not open for any trip which would have included an offending zig. Since human psychology is such that it would be difficult to entirely resist opportunities to test one's degree of freedom, she may need to agree to temporarily have the memories of that chronovisor session blocked so that she will be able to open the CTC which will allow her to embark on the corresponding trip. However, such a memory block would not be necessary if she merely decides to do everything she chronovised. A case where she has chronovised herself doing one thing on an upcoming time trip, but then chooses to do something else, is impossible, because that would mean that there would not have been such an upcoming trip to the past to chronovise in the first place.

This chronovisor scenario raises a topic with relevance to foreknowledge machines that has yet to be mentioned: Attempting to view one's own future actions would strongly tend to induce an interference viewing scenario. It is likely that an organization which uses foreknowledge machines, chronovisors, and time machines would discourage operators of foreknowledge machines and chronovisors from attempting to view their own personal futures, especially personal futures that are to occur in the past during time travel excursions, since reception of such information in the later case could greatly complicate the chances of opening the required CTCs. Rather than ever being exposed to direct viewer foreknowledge of their own future actions, or chronovisor data of upcoming time trips, field agents would typically receive dossiers which contain just the information deemed necessary for their mission by operational support specialists who have reviewed the relevant footage received by foreknowledge machine or chronovisor operators.

Before moving on, it is necessary to deal with a few loose ends. Namely, it is important to discuss how self-existing objects and instances of auto-generated information may be dispelled.[30] An insightful paper by Gustavo Romero and

[30] The following sources discuss or implicitly discuss self-existing objects, auto-generated information, or both: Lewis, D., "The Paradoxes of Time Travel," *American Philosophical*

Diego Torres presents the following example of the kind of situation in which the possibility of a self-existing object has been imagined:

> Suppose that... a time traveler takes a ride on a time machine carrying a book with her. She goes back to the past, forgets the book in... [what will be] her laboratory, and returns to the future. The book remains then hidden until the time traveler finds it just before starting her time trip, carrying the book with her.[31]

What a strange mystery such an object would be. "There is just a book never created, never printed, but, somehow, existing in space-time."[32] The problem of auto-generated information is more involved. Lloyd *et al.* refer to it using a different name in the following example:

> ...P-CTCs provide a distinct resolution to Deutsch's unproved theorem paradox, in which the time traveler reveals the proof of a theorem to a mathematician, who includes it in the same book from which the traveler has learned it (rather, will learn it). How did this proof come into existence?[33]

Quarterly, 13 (1976): 145-152. Editorial, "Analysis 'Problem' no. 18," *Analysis*, 39 (1979): 65-66. Harrison, J., "Report on Analysis 'Problem' no. 18," *Analysis*, 40 (1980): 65-69. Levin, M. R., "Swords' Points: [Analysis 'Problem' no. 18]," *Analysis*, 40 (1980): 69-70. Denruyter, C., "Jocasta's Crime: A Science Fiction Reply: [Analysis 'Problem' no. 18]," *Analysis*, 40 (1980): 71. Godfrey-Smith, W., "Travelling in Time: [Analysis 'Problem' no. 18]," *Analysis*, 40 (1980): 72-73. Nerlich, G., "Can Time Be Finite?" Pacific Philosophical Quarterly, 62 (1981): 227-239. MacBeath, M., "Who was Dr. Who's Father?" *Synthese*, 51 (1982): 397-430. Deutsch, D., "Quantum mechanics near closed timelike lines," *Physical Review D*, 44 (1991): 3197-3217. Lossev, A., Novikov, I. D., "The Jinn of the time machine: non-trivial self-consistent solutions," *Class. Quantum Grav.*, 9 (1992): 2309-2321. Visser, M., Lorentzian Wormholes: From Einstein to Hawking, (New York: AIP Press, 1996). Smith, N. J. J., "Bananas Enough for Time Travel?" *British Journal of the Philosophy of Science*, 48 (1997): 363-389. Gott, J. R., Li, L.-X., "Can the Universe Create Itself?" *Physical Review D*, 58 (1998): 023501. Romero, G. E., Torres, D. F., "Self-existing objects and auto-generated information in chronology-violating space-times: A philosophical discussion," *Mod. Phys. Lett. A*, 16 (2008): 1213-1222. Lloyd, S., Maccone, L., Garcia-Patron, R., Giovannetti, V., Shikano, Y., Pirandola, S., Rozema, L., Darabi, A., Soudagar, Y., Shalm, L., Steinberg, A., "Closed timelike curves via postselection: theory and experimental demonstration," *arXiv*:1005.2219v1 (2010): 5 pages. Lloyd, S., Maccone, L., Garcia-Patron, R., Giovannetti, V., Shikano, Y., Pirandola, S., Rozema, L., Darabi, A., Soudagar, Y., Shalm, L., Steinberg, A., "Closed Timelike Curves via Postselection: Theory and Experimental Test of Consistency," *Physical Review Letters*, 106 (2011): 4 pages. Popular books also touch upon such topics. In particular, see Paul Nahin's indispensable time travel compendium. Nahin, P. J., *Time Machines: Time Travel in Physics, Metaphysics and Science Fiction* (New York: Springer-Verlag and AIP Press, 1999).

[31] Romero, G. E., Torres, D. F., "Self-existing objects and auto-generated information in chronology-violating space-times: A philosophical discussion," *Mod. Phys. Lett. A*, 16 (2008): 1213-1222.

[32] Ibid.

[33] Lloyd, S., Maccone, L., Garcia-Patron, R., Giovannetti, V., Shikano, Y., Pirandola, S., Rozema, L., Darabi, A., Soudagar, Y., Shalm, L., Steinberg, A., "Closed Timelike Curves via Postselection: Theory and Experimental Test of Consistency," *Physical Review Letters*, 106 (2011): 4 pages.

Both of these problems are dispelled in a relatively straightforward manner, for similar reasons. As far as self-existing objects are concerned, here is the standard way of explaining why they could not exist: All physical objects undergo microscopic structural changes as they age, i.e., they accumulate "entropic degradation."[34] When earlier states of an object have less degradation, and later states have more, there is no problem—this even holds for an object sent through a CTC, so that its more degraded states will end up taking place at an earlier calendar date. However, in any would-be self-existing object, a reversal of entropic degradation to allow a precise return to some target state is always required to complete the loop without contradiction. Consider whether a human being could be a self-existing object without an impossible age reversal somewhere within the required life-loop, and the answer is clear. Such ineradicable contradictions or impossibilities always lurk within all would-be self-existing object situations.[35] Of course, CTCs will only open in the absence of inconsistencies. How appropriate that the puzzle of self-existing objects solves itself.

What about unproved theorems? A deeper analysis of why self-existing objects are not possible provides insights which lead to understanding. What prevents all the entropic degradation accumulated in the book on one leg of an imagined object-loop from being gradually reversed as it heads back to any given starting point, in order so that no discontinuity would be present? A book consists of several trillion particles, all oscillating and jostling about on different vectors. In the course of every second, a small percentage are naturally dislodged by this activity from their previous positions, and some even leave the book entirely. The book is never the same from moment to moment, on any

[34] Romero, G. E., Torres, D. F., "Self-existing objects and auto-generated information in chronology-violating space-times: A philosophical discussion," *Mod. Phys. Lett. A*, 16 (2008): 1213-1222.

[35] In 1992, physicists Andrei Lossev and Igor Novikov, who use the term 'Jinnee' to refer to any individual self-existing object (pluralized as 'Jinn'), made the following observation: "Among macroscopic objects the only really good candidate to be a Jinnee that we have found is the black hole. It seems that black holes cannot become older in a way that cannot be reversed by giving them some energy." While this interesting idea might sidestep the entropy objection, it does not open the conceptual way for self-existing objects. This follows for an astonishingly simple reason. Any collaboration to support the actualization of a self-existing object, by adding just the right amount of energy to a black hole at just the right time, must consist of at least two stages. To favor black hole Jinn as much as possible, assume a very large permanent natural wormhole in deep space, with mouths that are relatively close, separated by only a few light-seconds. Assume also that any object which enters the wormhole's future mouth will come out of its past mouth a month earlier. In the first stage of such an effort, a team must wait for the black hole in question to emerge from the past mouth of the wormhole, in order to immediately measure its energy content. The second stage would involve adding precisely the required amount of energy to the same black hole, using data from the first stage, and getting it to enter the future mouth of the wormhole. But, there is already a problem with this story. The first stage cannot begin until time α, defined as one month before the second stage will be completed, since the black hole cannot emerge from the past mouth any earlier than a month before it enters the future mouth. However, the second stage also could not commence until after time α, as this would be the earliest opportunity for anyone to see the supposed black hole and begin working on it. From these two conditions, it is clear that time α could never arrive. Lossev, A., Novikov, I. D., "The Jinn of the time machine: non-trivial self-consistent solutions," *Class. Quantum Grav.*, 9 (1992): 2309-2321.

physically-relevant timescale. In order to return the book to any previous state, a tremendous amount of information about that state would have to have been instantly cataloged. Complete knowledge about where each particle had been would be needed. Then, of course, some way of returning each book particle to its original position, and removing all the particles that had settled into the book from the environment, would have to be devised. Imagine for a moment that all these feats could be achieved. Would that do it? Even after all that work, it turns out that such a process would not get the book anywhere close to the way it had been. This is because each particle (i.e., atom or molecule) would also have to be given the exact amount of kinetic energy that it had had in the target configuration, on exactly the same vector, and all their internal quantum states would also have to perfectly match. These requirements enormously increase the already astronomical amount of information that would be required. Setting aside all the insurmountable feasibility considerations with respect to how particles might be returned, removed, accelerated, decelerated, and internally quantum-matched in order to achieve the target state, the problem of restoring the book is really an information problem. So, there is no wonder that there must be a discontinuity of information within any imagined self-existing object. Now, cases of would-be unproved theorems would also involve a discontinuity of information, but the amount of information would be several orders of magnitude less. One difference that might be noted is that any case of auto-generated information would constitute a discontinuity of information in the universe as a whole, rather than within an imagined object-loop. Of course, an imagined object-loop, if it could exist, would have to be part of the universe, so on another level of analysis there is ultimately no difference.

Now, from a more general perspective, the grandfather paradox is also ruled out because bilking would lead to a discontinuity of information within the universe as a whole. So, that which rules out the grandfather paradox is another consequence of the mechanism which rules out unproved theorems: No CTC will ever open that would lead, even accidentally, to a discontinuity of information.

These findings are consistent with the manner in which cases of auto-generated information have been mathematically dispelled by Lloyd *et al.*, insofar as their applicable P-CTC circuit delivers, "a random mixture of all possible 'proofs,'"[36] "The circuit is unbiased as to the value of the 'proof' bit, so it automatically assigns that bit a completely mixed value."[37] The logic of what their schematic model indicates is clear. All possible "proofs" taken together must be maximally ambiguous with respect to any specific proof, so their model manages to mathematically communicate that no information can be created within an "unproved theorem paradox circuit."[38]

[36]Lloyd, S., Maccone, L., Garcia-Patron, R., Giovannetti, V., Shikano, Y., Pirandola, S., Rozema, L., Darabi, A., Soudagar, Y., Shalm, L., Steinberg, A., "Closed Timelike Curves via Postselection: Theory and Experimental Test of Consistency," *Physical Review Letters*, 106 (2011): 4 pages. In this quotation, the word 'proofs' is in quotes to indicate that all possible proofs must consist of "proofs" that are merely gibberish, i.e., strings which are not proofs at all.

[37]Ibid.

[38]Ibid.

An interesting implication of the impossibility of cases of auto-generated information is that it effectively sandboxes different time periods from one another, to some degree, insulating the vast majority of people in earlier periods from information about the innovations and inventions of later periods. This would hold even in a world where foreknowledge machines and pastward time travel have been used for centuries. This is because the impossibility of auto-generated information means that it is physically impossible to provide either an author who originates a given set of conceptual innovations, or the original inventor of a given technology, with those very innovations or inventions. Of course, this is because anyone who might try to supply such things to such an author or inventor must have gotten such information from that author or inventor. Now, it would certainly be possible for foreknowledge machine operators and time travelers to gain or bring back information from the future, but there is no way for anyone with access to such information to tell a given author or inventor whose work they have learned about in their studies of the future, anything specific about what he or she will do. The most they could arrange would be to vaguely but powerfully encourage and inspire him throughout his life, on occasion, since childhood.

6 Matched Pairs in the Future-Making Process

The postselected, self-adjusting, cyclical, self-consistent model which supports view-travel unification has a very important feature: Cyclical matching guarantees that any instance of viewer foreknowledge must match the future outcome it reveals, in every detail. It is therefore appropriate to conceive of any such instance, together with its associated outcome, as a matched pair.

A good way to explain the mechanism at work in this cyclical matching process involves an important result of quantum mechanics that was masterfully presented in a lecture, quoted below, by the great physicist Richard Feynman. David Pegg discusses this result in his 2005 article, "Quantum Mechanics and the Time Travel Paradox":

> It is not totally surprising that a principle applying to classical physics has a quantum mechanical basis. The classical principle of least action can be explained in terms of the addition of amplitudes associated with the possible paths. The amplitudes for all paths except for those in the region of the path of least action cancel, so the probability for finding that the system has taken a path not near the path of least action is zero. This explains how the system "knows" to take the path of least action.[39]

With respect to the generation of viewer foreknowledge from foreknowledge machines, the least action problem that nature would have to work out would be enormously complex, for it would necessarily involve wavefunction amplitude

[39] Pegg, D. "Quantum Mechanics and the Time Travel Paradox," *arXiv*:quant-ph/0506141

addition (and so, effectively, subtraction) throughout all intervening physical situations leading to the outcome displayed. To gain more insight into what this means in the current context, consider what Pegg wrote next:

> In this paper we suggest that closed causal cycles are sorted out by a similar mechanism. Only those cycles with a net non-zero amplitude have a non-zero probability of occurring and these are the consistent cycles.[40]

Note that the approach Pegg advocated in 2005 is perfectly consistent with the more fleshed-out work of Lloyd *et al.*, and that it has application here due to view-travel unification. A given cycle in the case of foreknowledge machines begins with viewer foreknowledge of an outcome, continues through all the foreknowledge-informed actions and preparations, culminates in the outcome, and loops back to end where it began with the reception of viewer foreknowledge. On each end of the cycle is a member of the matched pair in question, so as soon as any viewer foreknowledge is received, such a "closed causal cycle" must have been "sorted out." This is the future-making process employed by groups who use foreknowledge machine technology. Solution of a massive applicable least action problem, would serve to explain how the outcome and, if also future-viewed, all of the intervening preparatory outcomes, would crystallize as viewer foreknowledge. Feynman gave an important lecture more than fifty years ago which provides deep insight into understanding this process:

> Is it true that the particle doesn't just 'take the right path' but that it looks at all the other possible trajectories? And if by having things in the way, we don't let it look, that we will get an analog of diffraction? The miracle of it all is, of course, that it does just that. That's what the laws of quantum mechanics say. It isn't that a particle takes the path of least action but that it smells all the paths in the neighborhood and chooses the one that has the least action by a method analogous to the one by which light chose the shortest time. You remember that the way light chose the shortest time was this: If it went on a path that took a different amount of time, it would arrive at a different phase. And the total amplitude at some point is the sum of contributions of amplitude for all the different ways light can arrive. All the paths that give wildly different phases don't add up to anything. But if you can find a whole sequence of paths which have phases almost all the same, then the little contributions will add up and you get a reasonable total amplitude to arrive. The important path becomes the one for which there are many nearby paths which give the same phase.[41]

His words reveal many key concepts of robust application here. Although Feynman referred to a particle taking a path, the kind of least action problem that

[40] Ibid.

[41] Feynman, R., *The Feynman Lectures on Physics*, (Palo Alto: Addison-Wesley Publishing Company, 1964).

nature would solve in cases of significant viewer foreknowledge would always involve vast collections of particles. Of course, everything he said about single particles would apply to any number of them.

It is highly relevant in this context to discuss the double-slit experiment. In the double-slit experiment, it is important to note that the characteristic interference pattern will still emerge even if photons are only introduced into the experimental apparatus one at a time. This is because the pattern built up over time is the result of the interference of probability amplitudes within the wavefunction. In single-photon cases, due to diffraction of the wavefunction at the slits, the least action problem for each photon path may be solved by any solution among a class of solutions, i.e., any solution which corresponds to detection locations of non-zero probability under the applicable wavefunction. So, each run of a single-photon double-slit experiment involves a stochastic quantum mechanical forking event which leads to one out of all the potential photon detection location outcomes. This raises an interesting and important question: What would happen if one were to use a foreknowledge machine in order to gaze upon a single-photon double-slit experiment to be performed in the future? Setting interference viewing scenarios aside, as they are a separate consideration, it will be shown that a foreknowledge machine would deliver viewer foreknowledge which details the precise location of each future photon detection outcome.

How could precise viewer foreknowledge of photon detection locations in future experimental runs be conceivable, if the single-photon double-slit experiment always involves a quantum mechanical forking event that can never be expected to produce precisely the same photon detection location from run to run? The answer comes from the cyclical matching viewpoint of viewer foreknowledge. While any number of final detection locations on the photographic plate or CCD are indeed possible within any given run of a single-photon double-slit experiment, the case of attaining viewer foreknowledge of an upcoming single-photon double-slit experiment is specially constrained. Namely, cyclical matching ensures that the detection location revealed in viewer foreknowledge of a given future experimental run will not differ from that which will occur during the experimental run itself. Viewer foreknowledge emerges only from a process of cyclical matching which will always produce a matched foreknowledge-outcome pair within a given closed causal cycle, and for this reason it confers certainty. Although quantum mechanics allows for many apparently inherently unpredictable possibilities, cyclical matching readily explains how viewer foreknowledge will never err, even regarding outcomes that are the result of long and enormously complex sequences of quantum mechanical forkings.

7 Further Details and Implications

The above analysis serves to integrate future viewing with time travel. This integration helps to further assure us that neither technology could destroy the mutual agreement of events in time, or be used to cause any sort of a paradox

(Lloyd *et al.* and others having already established this in the case of time travel). It has also been shown that no contradiction or loopy absurdity could arise, even if foreknowledge machines, Everett machines, chronovisors, line-of-sight past viewers, spaceships, and time machines were all freely used together.[42] Additionally, the limitations and properties of any outcome-informative future-viewing technology have been clarified. Most importantly, it has been shown exactly why outcome-informative future viewers could only present viewer foreknowledge, i.e., definite and correct information about future outcomes, within non-interference viewing scenarios.

If time machines and foreknowledge machines exist, or are ever invented in a non-academic setting, many societal and geopolitical reasons justify why they have remained, or could be expected to remain, secret for decades. In this regard, any group possessing such technology would have an ace up its collective sleeve; they would be able to know with certainty that the existence of foreknowledge machines will be kept secret—for as long as it is foreseen that they will be kept secret—and that any outcomes which have been witnessed in viewer foreknowledge will not be divulged to any party that will prevent them. Every aspect of operational security could always be confirmed via viewer foreknowledge itself.

This seemingly magical ability emerges from the realization that as soon as an operator would "dial in" a future spacetime coordinate and receive viewer foreknowledge of a given outcome, all the events leading to that outcome, if then viewed, would also be received as viewer foreknowledge. Foreknowledge machines will always detect interference viewing scenarios by supplying only ambiguous information, or failing to operate altogether. The chances of false viewer foreknowledge could thus be entirely eliminated through sufficient operator protocols and redundancy. Now, once any foreknowledge machine provides viewer foreknowledge of a given outcome, all foreknowledge machines free of interference will deliver identical viewer foreknowledge of it.

One implication of this is that individuals within groups who have learned of a given future outcome in the form of viewer foreknowledge could try to prevent the outcome all they want, but ultimately they would either decide to

[42] However, one major conundrum has yet to be addressed. Earman's rocket is a famous philosophical time travel puzzle, proposed by the philosopher John Earman in 1972, which once appeared to be unsolvable without resorting to coincidental malfunctions or timeline bifurcation. Earman's rocket is programmed to launch its probe back in time if it does not detect its probe earlier, but it will not launch its probe if it does detect it—the classic "it doesn't if it does, and does if it doesn't" conundrum. The answer in the context of the work of Lloyd et al. is simple: In cases of probe non-detection, the rocket's attempts to open a CTC in order to launch its probe will always fail, not due to a coincidental malfunction, but due to the proper functioning of the laws of physics associated with CTCs. The case of probe detection is even easier: If Earman's rocket is functioning as designed, it will never detect its own probe earlier, since it could not ever open a CTC. Only a malfunction which effectively reverses its programmed behavior could allow it to open a CTC. An extension of Earman's rocket puzzle, advanced by Jenann Ismael, is addressed in a similar manner. Earman, J., "Implications of Causal Propagation Outside the Null-Cone," *Australasian Journal of Philosophy*, 50 (1972): 222-237. Ismael, J., "Closed Causal Loops and the Bilking Argument," *Synthese*, 136 (2003): 305-320.

stop trying or they would fail, just as viewer foreknowledge also would have shown. As will be established in the next paragraph, once viewer foreknowledge which details a given outcome has been received by a foreknowledge machine, all efforts to prevent that outcome based on such information will be unsuccessful.

The original pointer position experiment may be modified to demonstrate this. Imagine that the experimental protocol were to allow two programs to be run sequentially at t_{B}. In this modified setup, the first of these programs can be any of the interfering programs, P-1 through P-359, and the second program will be P-0. In this modified experiment, no matter which interfering program runs first, the t_{A}-stationed viewer will display viewer foreknowledge of the t_{C} pointer position, due to the adjustments carried out by P-0 before the computer halts. In this modified setup, the first program represents an unsuccessful effort to interfere with the outcome which the t_{A}-stationed viewer was able to receive as viewer foreknowledge, due to the corrective action of P-0. Now, consider what would have been observed if this corrective program had not been present. In such a case, the experiment would be in its original form, so viewer foreknowledge of the t_{C} pointer position would not have been accessible to the t_{A}-stationed viewer. Therefore, receiving viewer foreknowledge about a future outcome with a foreknowledge machine means that such foreknowledge will not be used to prevent the outcome.

This confirms that, "once viewer foreknowledge which details a given outcome has been received by a foreknowledge machine, all efforts to prevent that outcome based on such information will be unsuccessful." Furthermore, since people who are not aware of such information would probably not be aware of the pending outcome, one may automatically conclude that nearly all efforts to prevent the outcome will be unsuccessful. Any other efforts to prevent the outcome could only occur to parties who have somehow uncovered clues, strictly unrelated to future viewing, which suggest that such an event will probably happen, or might happen. However, if any party without the benefit of viewer foreknowledge were to succeed in preventing the outcome received as viewer foreknowledge, then whatever would have taken place instead of the prevented outcome would have been what the foreknowledge machine would have received in the first place. So it may be concluded that no party, whether aware or unaware of viewer foreknowledge pertaining to a given outcome, can possibly be successful in preventing that outcome. Viewer foreknowledge cannot be used to try to prevent the outcomes it reveals; viewer foreknowledge is inviolable.

However, the opposite transition is available: Ambiguous information from a foreknowledge machine (or no information at all), pertaining to what will take place at a given future spacetime coordinate, can always be replaced by viewer foreknowledge under another viewing scenario which will become accessible when the context changes.

In order to provide an example of a transition from an interference viewing scenario to a non-interference viewing scenario, consider the original pointer position experiment carried out during runs of interference programs P-1 through P-359: At t_{A}, a future-viewing of the t_{C} pointer position will, at most, yield only ambiguous information. The computer will execute an interfering program at t_B and it will halt strictly before three seconds have elapsed. Now, let '$t_{\mathrm{B}+3}$' specify the time coordinate three seconds after t_B. It is clear that, were an effort made at $t_{\mathrm{B}+3}$ to future-view the t_C pointer position, viewer foreknowledge would result. This is because a non-interference viewing scenario exists by $t_{\mathrm{B}+3}$, for the computer has halted.

So, viewer foreknowledge will always become accessible to a foreknowledge machine when the context changes, but must the context always change? Yes; at least during the very last moment before an outcome occurs, an interference viewing scenario with respect to that outcome cannot exist. Consider the most extreme case: One Planck time (approximately $5.4 \cdot 10^{-43}$ seconds) before a given outcome occurs, there is literally no physically meaningful amount of time remaining to allow any system to process or act upon any future-viewed information about that outcome. At such a late stage it clearly would be impossible for future-viewed information about an outcome to be used to interfere with it. Of course, while this means that a transition between ambiguous and definite information must always occur before every outcome, in such an exaggerated case, the operator would only see and understand the output of the foreknowledge machine well after the corresponding event has already occurred. So, the real value of this demonstration of concept is to confirm that future viewing is consistent with past viewing in general—which always operates within a non-interference viewing scenario—since every possible interference viewing scenario with respect to a given future outcome must disappear before that outcome becomes an element of the past.

As mentioned above, it is also the case that a separate foreknowledge machine which is not connected to the computer in control of the pointer will always receive viewer foreknowledge. Only the viewer involved in the experiment will be hindered. Closely related to this, it is somewhat ironic that only those who will not (including those who cannot[43]) act upon viewer foreknowledge will remain in a non-interference viewing scenario, and thereby continue to have uninterrupted viewer foreknowledge of nearly all outcomes. However, even an ostensibly inert operator cannot gain viewer foreknowledge about all outcomes: Since it is impossible for anyone to not act, due to the fact that any effort to avoid acting is itself an action, an operator who attempts to view her own future actions will tend to place herself in an interference viewing scenario.

A great deal of this work has been devoted to the issue of interference viewing scenarios, but an important question about them has not yet been addressed. Would a group possessing foreknowledge machines ever encounter interference viewing scenarios with respect to world outcomes? While it has been shown that interference viewing scenarios could be arranged in a laboratory, could they ever arise when foreknowledge machines are applied to understanding future historical events? In the laboratory, interference viewing scenarios arise when no instance of definite and correct information about a given outcome, i.e., no instance of viewer foreknowledge, is possible. Again, this would occur

[43]In *Agammenon*, Apollo's edict effectively puts Cassandra in a non-interference viewing scenario with respect to any future outcome too big for her to prevent alone.

in situations where any example of definite information would necessarily be incorrect, which would force a foreknowledge machine to provide either ambiguous information, or none at all. It is difficult to imagine an interference viewing scenario in the case of a future historical event, for this would mean that no instance of viewer foreknowledge pertaining to that event could be consistent with its details. Instead, a case that has already been mentioned would happen frequently, wherein a future historical event which has been received in viewer foreknowledge is engineered by groups with foreknowledge machines—a special and important kind of non-interference viewing scenario. The rest of the paper will be about foreknowledge machines and world outcomes.

The following issue in this context is critical in the conceptual exploration of foreknowledge machines: What prevents foreknowledge machines from ever becoming the nightmarish contraptions that Cassandra machines would be, if Cassandra machines were possible? The answer to this question emerges from the cyclical basis of view-travel unification. Remember, "cyclical matching guarantees that any instance of viewer foreknowledge must match the future outcome it reveals, in every detail." Once an instance of viewer foreknowledge is obtained, one does not simply discover what the future will be, the way one might discover the activities of microbes by peering into a microscope. Instead, every relevant future action (leading to the future-viewed outcome) of every individual who watches, will watch, or will be briefed on a given instance of viewer foreknowledge, and the actions of everyone who will receive commands or will be subtly guided on its basis, must automatically and instantly factor into the formation of the matched pair in question. It would be amazing to witness, that although this future-making process always plays out over the entire cycle in question (which might span years, decades, or even centuries), its full and final results would always necessarily coincide with the reception of viewer foreknowledge. One can conceive of viewer foreknowledge and its paired future outcome as emerging together from a complex, behaviorally and thus mentally influenced optimization process within the corresponding closed causal cycle. The result is necessarily a perfect match, optimized with respect to every aspect of the arena in which all the preparatory and culminating events will transpire, an arena which especially includes behavioral responses which emerge from a great deal of thought, due to the fact that viewer foreknowledge has been received (by as many parties, using as many foreknowledge machines, as many times as apply), over the entire cycle in question. So, the cognitive processing of all actors, who will be affected by and who will affect any aspect of the pair, must necessarily be fully integrated into the process. Now also, if a given instance of viewer foreknowledge reveals events that will occur independently of the reception of viewer foreknowledge, then the future cognitive processing of actors who are completely unaware of foreknowledge machines will be factored into the formation of the corresponding matched pair.

A unique future emerges from this complex interplay; it is the one future which corresponds perfectly with all the details of how it was generated in the cooperative future-making process which in many cases, as a matter of logical necessity, cannot be divorced from the fact that viewer foreknowledge of that very future has been received. It would always be a custom-fit future we make for ourselves with willing hands. So, it should be clear that foreknowledge machines, whether they already exist or have yet to be technologically realized, are not to be feared.

Given all of the amazing properties of foreknowledge machines, any group which possesses them could be expected to go to great lengths, both to conceal the existence of the underlying technology and to regulate the flow of viewer foreknowledge. After all, if knowledge is power, what does that make viewer foreknowledge? Of course, as has already been mentioned, foreknowledge machines would guarantee that any given fact will remain secret for precisely as long as the relevant viewer foreknowledge shows that it will remain secret. Any day of reckoning would be foreseen, and thus fully planned for, well in advance.

While any group with foreknowledge machines would have a powerful influence upon future events, for reasons already explained, having a powerful influence over what will happen and deciding what will happen are two different things. Such a group would quickly come to realize that even with all the potent technology at their disposal, they still would not be in a position to decide what the future will be. They would see that it is not them, but rather the quantum workings of nature within the world situation, a world situation that now very influentially includes foreknowledge machines, which is ultimately determining the course of history. This follows for a few interrelated reasons. First of all, they could not ever cause outcomes contrary to any instance of viewer foreknowledge, so whatever they find on their screens is precisely what they and the rest of the world will end up experiencing. Furthermore, it is likely that nearly every instance of viewer foreknowledge pertaining to any historically significant event they might receive would involve outcomes they did not plan in any traditional sense, for how could they know details about the future other than through viewer foreknowledge, communication with cooperative future-dwellers, or by traveling to the future and returning with information? Since all of these methods respect the second-time-around fallacy, as soon as they might come to find out what the future holds, they could not act in any way to alter it. Obviously, then, any future outcomes such a group could become acquainted with through viewer foreknowledge, or by any other means, would not have been conceived by them or planned by them in any traditional sense, even though their resultant actions, which would have to include a great deal of planning, could indeed turn out to be instrumental in the fruition of such outcomes. While all observations so far have hypothetically assumed just one secret group with foreknowledge machines, they would all still apply if several secret groups were to independently invent them. This is because the inviolability of viewer foreknowledge would necessarily unite groups who use foreknowledge machines, such that they can always be considered to act in concert; they would all necessarily and willingly move toward the same outcomes together.

Realize also that a group with foreknowledge machines could not choose to stop using them if their screens continue to deliver viewer foreknowledge that they will continue to use them. In a sense, any group which begins to use foreknowledge machines and other related technologies has embarked on a course of action from which they cannot arbitrarily choose to diverge. While they might have imagined at the outset that such advanced technologies would help them further their own agenda, within a few months it would dawn upon them that what has effectively become their agenda has been and will continue to be given to them by the overall process which generates viewer foreknowledge, and also, that there is nothing they can do about it.

How could the laws of nature, calculating within ever-lengthening viewer foreknowledge cycles, have an agenda? This is really the wrong question. Think about it this way: Do the laws of nature have an agenda to make rubber ducks float in bathtubs? No, of course not; rubber ducks float in bathtubs due to the properties of rubber ducks, bathtubs, liquid water, and strong gravitational fields. Whenever these elements are brought together in the relevant way, rubber ducks will float. The same kind of explanatory understanding must also apply to whatever seeming agenda the laws of nature would appear to hand down to such groups through cyclical matching within the world situation.

Can efforts to arrive at an explanatory understanding of how the laws of nature could seem to manifest an agenda when technologically funneled into the production of viewer foreknowledge, give any hint as to what the ultimate "goal" of such an apparent agenda might be? Think about a rubber duck introduced under water, at the bottom of a bathtub. In a strong gravitational field, this represents an imbalance of density distribution that naturally produces a force which will act to make the duck rise to the surface, since water, which is of greater density than the average density of the hollow duck, will fill in beneath it until a balance of density distribution has been restored. Once there is no more water above the duck to fill in beneath it, the duck will be resting on the water's surface in a state of equilibrium. Now, the initial discovery and perfection of future-viewing technology, which would certainly be carried out in secret, could also represent the introduction of an imbalance capable of producing a force which would bring about some final state. As one ponders these issues, an idea about what this final state might be becomes increasingly clear. There are strong reasons for believing that this final state can be none other than the introduction of foreknowledge machines to the world.

Surely, if only one or a handful of groups were to possess foreknowledge machines, rather than the whole of humanity, such a condition would represent an imbalance, a non-equilibrium state. This is because a great deal of work would have to be done in order to keep foreknowledge machines and viewer foreknowledge secret. Such work can be likened to a hand holding a rubber duck under water, to prevent it from reaching the natural equilibrium state of floating on the water's surface. Now, a person could choose to hold a rubber duck under water for a long time, since she solely decides what to do with her hands. However, as already established, what the "hands" of individuals in groups with foreknowledge machines will ultimately do is, in some sense, not fully up to them. Remember, they do not decide all on their own what their agenda will be; they have willingly given this up in favor of something greater. Their agenda is "decided" by the physics of their unique technological position. The process behind viewer foreknowledge continually informs them of what they, as a whole, will choose to do willingly, and they must defer to its inherent wisdom—the wisdom of their own future thoughts and actions in light of viewer foreknowledge—to discover what their direction will become. So, it is certainly conceivable, and even highly likely, that the relevant equilibrium state in this context, i.e., the introduction of foreknowledge machines to the world, might eventually become their goal.

So, no matter how secretive in origin, groups with foreknowledge machines eventually would probably not wish to permanently keep the technology all to themselves. In any case, of course, they would be aware of the physical impossibility of preventing any given future that they might find in viewer foreknowledge. In all likelihood, they would foresee something like one of the following sets of future outcomes: Either they would find that they will eventually reveal foreknowledge machines (and possibly time machines) to the world themselves, or that they will subtly or secretly help others to "discover" such technologies, or that they will simply not interfere with an eventual independent rediscovery of foreknowledge machines and their subsequent worldwide proliferation. One may conclude that groups which have developed such technologies would witness something like one of these outcomes in viewer foreknowledge, to an overwhelming degree of likelihood, since the only alternative would correspond to the future-making process "deciding" to keep foreknowledge machines and viewer foreknowledge a cloistered secret permanently. Such an outcome would be almost as unlikely as a rubber duck remaining underwater forever. In the end, however the grand breakthrough might occur, the acknowledgement and demonstration of foreknowledge machine technology would surely be an event to be counted among the most significant developments in human history, alongside the invention of writing, the adoption of farming, and the discovery of fire.

Once foreknowledge machines would be revealed (or are revealed), the process of their integration into the conduct of civilization as a whole would (or will) begin in earnest. Interestingly, the machines themselves, in a manageable, step-by-step fashion, would show us how this amazing revolution is to be accomplished. Also, the slow but sure process of coming to terms with and understanding all the cruel actions that were taken prior to the unveiling of foreknowledge machines could get underway. Many of the historically significant events that foreknowledge machine groups might foresee in the decades prior to the introduction of foreknowledge machines to the world, would seem senselessly cruel outside of the paradigm of viewer foreknowledge. However, once everyone has been inducted into this paradigm, we would begin to understand that such events were not planned by them in any traditional sense, for they could not have been altered once they were received as viewer foreknowledge. The world as a whole would begin to understand and accept that, no matter how cruel, such events had been part of a necessary stage in the progression which led to the end result, a world resting in equilibrium, united permanently through viewer foreknowledge. The people of such a world would eventually agree that the foreknowledge machine groups of the past had no choice other than to do what they did. The bright side of all this is that there is a sense in which the cruelty of an era of secret viewer foreknowledge would necessarily vanish in an era of public viewer foreknowledge. A world wherein an entire civilization benefits from viewer foreknowledge of large-scale outcomes would obviously be drastically different, and much better for everyone involved, than the transitional world involving secret foreknowledge machine groups before it. It is up to us all, the whole of humanity, to dream of such a world, to dream of what we might create together.

Might achieving such an equilibrium state be the final piece of a cosmic puzzle that all civilizations must place, essentially on their own, in order to qualify for integration with other civilizations in the universe? If foreknowledge machine technology is possible, imagine the peace other civilizations know, a peace of certainty which naturally emerges through shared equilibrium with other intelligent species who have achieved the same lofty status throughout space and time. Maybe foreknowledge machines and realistic time machines are nothing more than compelling and logically interrelated fictions. However, maybe these technologies are achievable, or have already been achieved, and are destined to form the very basis of our future.